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Pallan, Miranda J; Adab, Peymane; Sitch, Alice J; Aveyard, Paul

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Are school physical activity characteristics associated with weight status in primary school children? A multilevel cross-sectional analysis of routine surveillance data

Authors

1. Miranda J Pallan
   Public Health, Epidemiology & Biostatistics
   School of Health & Population Sciences
   University of Birmingham, UK

2. Peymane Adab
   Public Health, Epidemiology & Biostatistics
   School of Health & Population Sciences
   University of Birmingham, UK

3. Alice J Sitch
   Public Health, Epidemiology & Biostatistics
   School of Health & Population Sciences
   University of Birmingham, UK

4. Paul Aveyard
   Primary Care Clinical Sciences
   School of Health & Population Sciences
   University of Birmingham, UK

*Corresponding author:
Peymane Adab
Public Health, Epidemiology and Biostatistics
University of Birmingham
Edgbaston
Birmingham, B15 2TT
UK
Tel: +44 121 414 3777
Fax: +44 121 414 7878
Email: P.Adab@bham.ac.uk

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ABSTRACT

Background: The school environment potentially influences the development of childhood obesity. Changes to schooling could be used as an intervention to reduce obesity but the features of the school environment that influence obesity are unknown.

Aim: To estimate the interschool variation in BMI z-scores in primary school children and examine the individual and school physical activity characteristics contributing to this.

Methods: Cross-sectional analysis and multilevel modelling at individual and school level, with BMI standard deviation scores (z-scores) as the outcome. Individual and school data were obtained for 11,118 reception year children (age 4-5) and 10,151 year 6 children (age 10-11) from 296 primary schools in Birmingham. Data sources were the UK National Child Measurement Programme and the annual National School Sport Survey in 2006/7.

Results: In reception year children 4.2% of the in variation BMI z-scores is attributed to differences between schools. Individual characteristics explained 24% of this between-school variation and certain school physical activity characteristics (the time schools devote to physical education) explained a further 28%. In year 6 children only 0.9% of the variation in BMI z-scores was between-school variation. BMI z-scores were significantly higher in year 6 than reception year children, with the largest increases between year groups in the South Asian and African-Caribbean ethnic groups. Deprivation was positively associated with BMI z-scores.

Conclusions: In addition to the association between individual characteristics and BMI z-score, there is a small but significant association between school characteristics and BMI z-score, which is in part explained by the time schools devote to physical education. This modest school effect has the potential to have a substantial impact on children's weight status at a population level.

INTRODUCTION

Obesity is an important health problem that has increased dramatically worldwide in both children and adults in the last four decades.[1] In the UK, despite a recent plateau in prevalence, childhood obesity levels remain high with 23% of children aged 4-5 and 34% of those aged 10-11 are overweight or obese.[2] Childhood obesity is associated with short and long-term adverse health consequences.[3-6]

The UK government has introduced policies to reduce obesity. In order to monitor trends, the height and weight of all primary school children are measured in their first and final year, and BMI is calculated to track prevalence patterns.[7] A key policy area for tackling childhood obesity is increasing children's physical activity through schools. In 2007 the government increased existing targets for provision of school physical activity from 2 to 5 hours per week, of which 2 hours should be high quality physical education.[8] A national annual survey of schools has been conducted since the introduction of physical activity targets in 2002 to monitor schools' progress.[9]

Evidence of effective ways of preventing childhood obesity is limited. Most prevention interventions that have been evaluated have had little or no benefit.[10-12] It is clear that a better understanding of the multiple factors that influence the development of childhood obesity is required in order to develop more effective prevention strategies.[13,14]

Much childhood obesity research has focused on individual risk factors, most of which are not amenable to change. Characteristics such as birth weight, genetic factors and parental weight status have consistently been shown to be associated with obesity.[15,16] There is also some evidence to suggest that children from lower socioeconomic groups or certain ethnic groups (particularly African-Caribbean and some South Asian groups) are more likely to be overweight or obese.[15,17-19]

However, there is increasing emphasis on environmental factors as determinants of obesity[20,21] and a need to develop and test interventions that target the environment. Variations in the school environment, including policies related to health behaviours, as well as more general aspects such as the educational environment, are associated with children's health behaviour, particularly smoking.[22,23] There is some evidence that this extends to childhood obesity. O'Malley et al. reported that 3% of variation in BMI across the USA, could be attributed to school characteristics.[24] Procter reported substantial variation in pupil obesity between 35 primary schools situated in a UK city.[25]

Several studies have sought to identify relationships between school characteristics and pupils' BMI. The school food culture, for example using food for rewards[26] and the availability of energy-dense food and sugar-sweetened drinks[27,28], have been shown to be associated with higher BMI, independent of individual characteristics. The influence of the school physical activity environment on obesity has been less studied. One US study found modest inverse associations between obesity and physical activity characteristics, such as the average number of days per week students engage in physical education and the proportion of pupils involved in interschool sports.[29] There is a larger literature reporting the association between school physical activity characteristics and children's physical activity levels. A recent review reported positive associations between characteristics of the physical environment of the school, such as amount of outdoor/green space and provision of physical activity facilities/equipment, and amount of physical activity undertaken by the children.[30]

Taken overall, the evidence suggests that the school context does influence childhood obesity. However the specific characteristics mediating this effect, particularly in relation to physical activity, are poorly understood. In this study data obtained through the National Child Measurement Programme (NCMP), together with routine data collected on school physical activity characteristics is used to estimate proportion of variation in BMI that can be attributed to differences between schools, and to explore the associations between individual and school physical activity characteristics, and childhood overweight/obesity.

METHODS

This study uses routine data collected in 2006/7 across primary schools in Birmingham, a large multicultural industrial city in England.

Individual level data

All schools are invited to participate in the annual NCMP. All reception year (age 4-5) and year 6 (age 10-11) children are eligible to participate and 'opt out' parental consent is obtained. Trained personnel weighed children in light clothing, without shoes to the nearest 0.1 kg using standard weighing scales, and measured heights to the nearest 0.1 cm using a free-standing stadiometer.[31] BMI was calculated and standard deviation scores (BMI z-scores) derived using the UK 1990 BMI reference curves for children.[32] Participants were categorised as healthy weight, overweight or obese using the 85th and 95th centile cut offs respectively, in line with NCMP guidance.

Parent-reported data were obtained from school records on age, gender, ethnicity and home postcode for each pupil. Postcodes were linked to UK Indices of Multiple Deprivation (IMD) 2007 scores[33] to derive a measure of deprivation. Ethnicity was collapsed into 6 groups; white, South Asian, Africa-Caribbean, Chinese and other Far East groups, mixed ethnicity, and unknown.

School level data

All schools are invited to participate in an annual survey undertaken as part of the national Physical Education, School Sport and Club Links strategy.[9] The survey asks questions related to physical activity opportunities provided by or linked to schools. Data extracted for schools used in this study included: number of minutes per week pupils spend in physical education, proportion of pupils spending at least 2 hours in high quality physical education each week, number of sports or physical activities provided by schools, proportion of pupils participating in intraschool competitive sports, proportion of pupils participating in interschool competitive sports, number of sports for which the school has links to clubs, and proportion of pupils participating in sports or clubs linked to the school.

Analysis

All analyses were undertaken using STATA (v11). Descriptive analyses were used to examine individual sociodemographic factors associated with obesity and school level variations in physical activity characteristics. Multilevel linear random effects models were developed using BMI z-score as the outcome, with pupils at level 1 and schools at level 2.

First, using data for both year groups, a null model was developed (model 1). School was included as a random effect in the null model, as the likelihood ratio (LR) test statistic was significant at the 5% level. Second, a model with the individual level variables (year group, sex, ethnicity, IMD score) as fixed effects was fitted, then random slopes and plausible two-way interactions were tested in the model and retained if they were found to improve the model fit, as judged by the LR test (model 2). Each school level variable was then tested in model 2 to estimate their regression coefficients. The final model (model 3) was developed by the adding school level variables and further plausible two-way interactions into model 2, and retaining them if they improved the model fit, as judged by the LR test.

Analysis of the combined data indicated differences between the two year groups. Therefore, separate models for each year group were developed using the same methods.

RESULTS

Of the 304 state primary schools in Birmingham, 296 (97%) participated in the NCMP. Valid data were obtained from 272 schools (89%, 11,118 pupils) for reception year and 240 schools (79%, 10,151 pupils) for year 6. Postcode data were obtained for 9530 reception year pupils and 8851 year 6 pupils. School data were obtained for 175 of the schools contributing individual data from reception year (5817 pupils) and 147 from year 6 (5566 pupils), 58% and 48% of all Birmingham state primary schools respectively. The analyses presented in this paper include all available data. Given the large amount of missing postcode and school level data, a sensitivity analysis was undertaken whereby all models were repeated using only the pupils with complete data both at the individual and school level (n=5,725 for reception year and n=5,435 for year 6). Very similar results were obtained so these sensitivity analyses are not presented.

The prevalence of overweight/obesity in the study sample was 22.9% for reception and 35.5% for year 6. Overweight and obesity prevalence by gender, ethnicity and deprivation are shown in Table 1. School data on physical activity indicators for included schools (196 schools) are summarised in Table 2. The mean time devoted to PE per week for all schools was 111 minutes (SD: 17.4, range: 60-165), which is less than the national 2 hour target. The crude overweight/obesity prevalence for each school varied greatly; from 0-50% in reception and 5-67% in year 6. The number of pupils measured in each year group ranged from 4-114.

Table 1: Overweight and obesity prevalence in reception and year 6 pupils in Birmingham primary schools

Characteristic	Reception			Year 6		
	Total study sample n (%)	**Overweight or obese n (%)**	**BMI z-score mean (SD)**	**Total study sample n (%)**	**Overweight or obese n (%)**	**BMI z-score mean (SD)**
Total	11,118 (100)	2554 (23.0)	0.26 (1.21)	10,151 (100)	3612 (35.6)	0.51 (1.31)
Gender						
Boys	5,821 (52.4)	1390 (23.9)	0.27 (1.25)	5,192 (51.2)	1971 (38.0)	0.58 (1.32)
Girls	5297 (47.6)	1164 (22.0)	0.25 (1.16)	4,959 (48.9)	1641 (33.1)	0.43 (1.30)
Ethnicity						
White	4,320 (38.9)	1024 (23.7)	0.43 (1.00)	4,334 (42.7)	1433 (33.1)	0.51 (1.19)
South Asian	3,467 (31.2)	733 (21.1)	0.08 (1.35)	3,034 (29.9)	1117 (36.8)	0.43 (1.46)
African-Caribbean	807 (7.3)	225 (27.9)	0.37 (1.26)	904 (8.9)	359 (39.7)	0.67 (1.33)
Chinese and other Far East	112 (1.0)	19 (17.0)	0.11 (1.22)	115 (1.1)	37 (32.2)	0.48 (1.14)
Mixed ethnicity	585 (5.3)	132 (22.6)	0.35 (1.11)	565 (5.6)	211 (37.4)	0.60 (1.25)
Unknown	1,827 (16.4)	421 (23.0)	0.16 (1.29)	1,199 (11.8)	455 (38.0)	0.52 (1.34)
IMD quintile[1]						
1	6,355 (66.7)	1493 (23.5)	0.25 (1.24)	5,751 (65.0)	2,109 (36.7)	0.53 (1.35)
2	1,402 (14.7)	316 (22.5)	0.36 (1.09)	1,350 (15.3)	481 (35.6)	0.56 (1.24)
3	1,120 (11.8)	258 (23.0)	0.33 (1.07)	1,115 (12.6)	358 (32.1)	0.49 (1.18)
4	457 (4.8)	84 (18.4)	0.28 (0.96)	410 (4.6)	125 (30.5)	0.31 (1.22)
5	196 (2.1)	36 (18.4)	0.31 (0.91)	225 (2.5)	63 (28.0)	0.31 (1.13)

[1]IMD scores are divided into quintiles using the quintile cut points for all small (postcode) area IMD scores in England. 1st quintile is most deprived.

Table 2: Physical activity characteristics of Birmingham primary schools (N=196)

School physical activity characteristic	Schools in Reception year analysis (N=175)		Schools in Year 6 analysis (N=147)	
	Mean (SD)	Median (IQR[1])	Mean (SD)	Median (IQR[1])
Minutes PE per week	109.94 (18.14)	120 (98-120)	112.14 (17.09)	120 (105-120)
% pupils engaging in ≥2 hours high quality PE per week	87.36 (23.49)	100 (88-100)	88.14 (23.26)	100 (90-100)
Number of sports activities offered by schools	15.36 (4.35)	16 (12-18)	15.97 (3.97)	16 (14-18)
% pupils involved in intra-school competitive sports	43.37 (34.56)	38 (14-70)	46.70 (35.37)	39 (18-73)
% pupils involved in inter-school competitive sports	28.65 (22.23)	24 (13-39)	29.34 (20.64)	25 (15-39)
Number of sports/activity clubs linked to school	5.09 (5.22)	4 (1-7)	5.49 (5.33)	4 (2-7)
% pupils participating in sports/activity clubs linked to school	28.93 (28.40)	22 (4-46)	28.45 (28.02)	22 (4-44)

[1]IQR=interquartile range

Multilevel analyses

The null model for all three analyses showed that there was a significant random effect for school (χ^2=219.00, p<0.0001 for reception year, χ^2=15.58, p<0.0001 for year 6, and χ^2=139.52, p<0.0001 for reception and year 6 data combined). The intracluster correlation coefficient (ICC) in each model was estimated as 0.042, 0.009 and 0.017 respectively, indicating that in reception, year 6 and both years combined, 4.2%, 0.9% and 1.7% of the variation in BMI z-scores is attributed to between-school rather than within-school variation.

Each school level variable was tested in the level 1 adjusted models and the regression coefficients obtained are presented in Table 3. All coefficients, with the exception of the percentage of pupils in interschool competitive sports for year 6 pupils, were negative, suggesting a trend towards an inverse association of school physical activity attributes with BMI z-score. However, most of these coefficients were not statistically significant. The coefficient for number of minutes spent in PE per week was statistically significant for the combined and reception year model. The number of sports activities offered by schools and the percentage of pupils involved in interschool competitive sports were just significant at the 5% level, when incorporated in the combined and reception year models.

Table 3: Regression coefficients for school level variables tested in models adjusted for individual factors (outcome: BMI z-score)

School physical activity variables	**Reception and year 6 combined model**		**Reception year model**		**Year 6 model**	
	Estimate (95% CI)	p	Estimate (95% CI)	p	Estimate (95% CI)	p
Minutes PE per week (10 minute increments)	-0.019 (-0.035, -0.004)	0.01	-0.026 (-0.047, -0.006)	0.01	-0.008 (-0.032, 0.016)	0.51
% pupils engaging in ≥2 hours high quality PE per week	-0.001 (-0.002, 0.0004)	0.22	-0.001 (-0.003, 0.001)	0.22	-0.0005 (-0.002, 0.001)	0.58
Number of sports activities offered by schools	-0.006 (-0.013, -0.0002)	0.04	-0.004 (-0.013, 0.004)	0.33	-0.008 (-0.018, 0.002)	0.14
% pupils involved in intra-school competitive sports	-0.0004 (-0.001, 0.0004)	0. 29	-0.001 (-0.002, 0.0004)	0.21	-0.0002 (-0.001, 0.001)	0.78
% pupils involved in inter-school competitive sports	-0.001 (-0.002, 0.0004)	0.18	-0.002 (-0.003, -0.00004)	0.04	0.0004 (-0.002, 0.002)	0.71
Number of sports/activity clubs linked to school	-0.004 (-0.009, 0.001)	0.15	-0.005 (-0.013, 0.002)	0.17	-0.002 (-0.010, 0.006)	0.61
% pupils participating in sports/activity clubs linked to school	-0.004 (-0.001, 0.001)	0.38	-0.001 (-0.003, 0.0002)	0.09	0.004 (-0.001, 0.002)	0.58

The final models are presented in Table 4. In the combined model, a random slope for year group made a significant contribution to the model fit, indicating that the between-school variance is not constant across year groups. Several individual level regression coefficients were statistically significant in the combined model. Overall, year 6 pupils had a higher BMI z-score than reception pupils. The significant year group-sex and year group-ethnicity interaction terms indicate that the difference in BMI z-scores between the two year groups varies with sex, and ethnicity. The mean difference in BMI z-score between reception and year 6 boys was 0.153, but in girls the mean difference between the two year groups was 0.051 (0.153 + year 6-female interaction term (-0.102)). Compared with white children the mean difference in BMI z-score between reception and year 6 increased by 0.205 for South Asian children (as indicated by the year 6-South Asian interaction term) and 0.274 for African-Caribbean children (as indicated by the year 6-African-Caribbean interaction term), suggesting that the difference in BMI z-score between children in reception and year 6 is significantly larger in these ethnic groups than in white children.

In the combined and the separate year group models, South Asian ethnicity was significantly inversely associated with increasing BMI z-score. In the year 6 model, African-Caribbean ethnicity was positively associated with BMI z-score and female sex was significantly inversely associated with BMI z-score. In the combined and the year 6 models, but not in the reception model, IMD score was positively associated with BMI z-score, indicating that less affluent children had higher BMI z-scores, adjusting for other factors. The only school level variable contributing to the models was the number of minutes of physical education per week, which was statistically significant in the combined and the reception models. This variable was not retained in the year 6 model as it did not significantly improve the model fit.

Table 4: Multilevel models for reception, year 6 and both year groups combined (outcome: BMI z-score)

	Reception & year 6 combined		**Reception**		**Year 6**	
	Coefficient (95% CI)	**p**	**Coefficient (95% CI)**	**p**	**Coefficient (95% CI)**	**p**
Fixed effects						
Constant	0.592 (0.410, 0.773)	<0.001	0.695 (0.455, 0.935)	<0.001	0.528 (0.448, 0.607)	<0.001
Individual						
Year 6[1]	0.153 (0.079, 0.226)	<0.001				
Female[2]	-0.032 (-0.91, 0.027)	0.29	-0.030 (-0.086, 0.025)	0.29	-0.144 (-0.198, -0.090)	<0.001
Ethnicity[3]		<0.0001		<0.0001		0.0001
South Asian	-0.333 (-0.412, -0.254)	<0.001	-0.333 (-0.413, -0.253)	<0.001	-0.100 (-0.170, -0.029)	<0.01
African-Caribbean	-0.099 (-0.235, 0.036)	0.15	-0.086 (-0.215, 0.044)	0.19	0.136 (0.036, 0.236)	<0.01
Chinese and other Far East	-0.207 (-0.479, 0.065)	0.14	-0.197 (-0.453, 0.058)	0.13	-0.053 (-0.300, 0.193)	0.67
Mixed ethnicity	0.004 (-0.120, 0.128)	0.95	0.010 (-0.107, 0.128)	0.86	0.089 (-0.028, 0.207)	0.14
Unknown	-0.196 (-0.324, -0.069)	<0.01	-0.192 (-0.316, -0.069)	<0.01	0.023 (-0.192, 0.238)	0.83
IMD Score (10 unit increments)	0.018 (0.004, 0.031)	0.01	0.008 (-0.010, 0.027)	0.385	0.018 (0.0004, 0.035)	0.045
Interactions						
Year 6-female	-0.102 (-0.187, -0.016)	0.02				
Year group-ethnicity		<0.01				
Year 6-South Asian	0.205 (0.089, 0.321)	0.001				
Year 6-African-Caribbean	0.274 (0.087, 0.462)	<0.01				
Year 6-Chinese and other Far East	0.049 (-0.343, 0.441)	0.81				
Year 6-mixed ethnicity	0.111 (-0.066, 0.288)	0.22				
Year group-unknown ethnicity	0.160 (-0.099, 0.420)	0.23				
School						
10 minute increments in PE/week	-0.020(-0.350, -0.005)	0.01	-0.026 (-0.047, -0.005)	0.01		
Random effects	**Variance (95%CI)**		**Variance (95%CI)**		**Variance (95%CI)**	
School	0.008 (0.003, 0.019)	<0.0001*	0.024 (0.014, 0.041)	<0.0001*	0.014 (0.006, 0.028)	<0.001*
Year group	0.016 (0.007, 0.037)					

Reference groups: [1]Reception year, [2]male, [3]white

*Likelihood ratio test for multilevel vs. linear regression

Contribution of individual and school characteristics to the variation between schools

Table 5 shows the within- and between-school variances for the combined, reception year, and year 6 null (model 1), level 1 variable adjusted (model 2), and fully adjusted (model 3) models. The individual characteristics included in model 2 explain 31%, 24% and 5% of the variation in BMI z-score between schools in the combined, reception, and year 6 populations respectively ((% between-school variation in model 1 - % unexplained between-school variation in model 2)/% between-school variation in model 1 x 100). The combined and reception models included school level variables (time allocated for physical education) and this explained a further 34% of the between-school variation in the combined model and 28% of the between-school variation in the reception model ((% unexplained between-school variation in model 2 - % unexplained between-school variation in model 3)/% between-school variation in model 1 x 100).

Table 5: Unexplained between- and within-school variance for the null, individual factor-adjusted, and fully adjusted multilevel models

	Null model (model 1)			**Model adjusted for individual factors (model 2)**			**Model adjusted for individual and school factors (model 3)**		
	Between school variance	Within school variance	Variation between schools	Between school variance	Within school variance	Unexplained variation between schools	Between school variance	Within school variance	Unexplained variation between schools
Reception & year 6 combined	0.027	1.569	1.69%	0.018	1.517	1.17%	0.008	1.351	0.59%
Reception year	0.061	1.391	4.20%	0.044	1.334	3.19%	0.024	1.182	1.99%
Year 6	0.015	1.707	0.87%	0.014	1.681	0.83%	0.014	1.681	0.83%

DISCUSSION

This study sought to examine between-school variation in relation to physical activity in schools using measures which have been the target of UK Government policy. There was a consistent relationship between positive physical activity characteristics and lower weight status in all models, although the majority were not statistically significant. This suggests that the school physical activity environment potentially influences childhood weight status.

Although most of the observed variation in BMI z-scores between schools is due to individual characteristics, this study showed that 4% and 1% of variation is at the school level for reception and year 6 children respectively. This small amount of unexplained variation between pupils' BMI z-score at the school level may give the impression that the 'school effect' is unimportant. However, at a population level the effect is considerable. Assuming this unexplained variation is caused by school factors, then the impact on pupil weight status of a “well” performing school (one SD above average) to a “less well” performing school (one SD below average) could be compared. In this scenario, reception year children would have a BMI z-score 0.31 points lower in the better performing school compared to the less well performing school. The corresponding figure for year 6 children is 0.24 points. This translates to a 9% difference in the proportion of children who are overweight or obese in reception year (22% in the “well” versus 31% in the “less well” performing school) and 7% difference in year 6 (31% and 38% respectively). Therefore, this school effect is worth investigating further.

In terms of pupil level characteristics, a relationship between ethnicity and weight status was observed, which differed in each year group. In comparison to white children, African-Caribbean children had the highest proportion of overweight/obesity in both age groups, with a bigger increment in BMI z-score from reception to year 6. South Asians had a lower prevalence of obesity than white children in both year groups, but there was a bigger increment between reception and year 6 compared to white children. Previous studies have suggested that UK South Asian children have more body fat, and higher cardiovascular risk at lower BMI compared to white children.[34,35] Thus, in terms of health consequences, the lower BMI z-scores for South Asian children may be misleading. Given that this is a cross-sectional analysis in two different year groups, there is a possibility that the larger increases in BMI z-scores observed between reception and year 6 in the South Asian and African-Caribbean ethnic groups are due to a cohort effect. However, these findings may suggest that obesity prevalence increases more sharply between early childhood and adolescence among South Asian and African-Caribbean children. Thus there may be a particular opportunity for obesity prevention in childhood in these ethnic groups.

A socioeconomic gradient was demonstrated in year 6, with increasing deprivation associated with higher BMI z-scores, in line with other epidemiological studies.[19,36] This gradient was not as evident reception year children in this study, although nationally the NCMP data has consistently shown a socioeconomic gradient in both year groups.[37] Birmingham is more deprived than most of the UK, and this is reflected in the study population (81% in the two most deprived quintiles; see Table 1). This may explain the lack of socioeconomic gradient in the reception year population.

This study includes data from a large number of schools and pupils covering a wide range of ethnicities. Height and weight data were collected using standard protocols and instruments by trained personnel, minimising the possibility of observer bias. Use of multilevel modelling enabled examination of the role of school characteristics independent of pupil factors in childhood weight status. However there are some limitations. Although participation of Birmingham schools in the NCMP was high (89% and 79% for reception and year 6 respectively), coverage within each school was incomplete. Parents may be more likely to decline measurement if the child is overweight or obese. Such selection bias may affect the observed prevalence of obesity, and therefore the interschool variation estimate.

Only half of the schools provided physical activity data, so it is possible that the schools included in the multilevel analyses differ from those with missing data. For example, schools with poor physical activity environments may be less likely to participate in the survey. Comparing children at participating schools with children from non-participating schools, a small but statistically significant difference in BMI z-score was found, with a higher mean BMI z-score in the latter group (0.34 vs.0.41, $p<0.0001$). Therefore if the non-responding schools do have less supportive physical activity environments, there would be an underestimation of the association between the school physical activity environment and obesity. A further limitation of the school physical activity data is that it is derived from a survey completed by school staff, and therefore the accuracy of the responses may vary. There is also potential for social acceptability bias (e.g. schools may report that they are providing more PE than they actually do because they are aware of the requirement to meet the national target). However, the mean number of minutes of PE provided by schools per week was below the national two hour target, which would suggest that this type of bias is not a major problem.

The cross-sectional nature of this study is also a limitation as the temporal sequence of observed associations cannot be determined. Despite these limitations, the findings highlight the potential influence of the school environment on childhood overweight and obesity, and indicate areas for future research and potential intervention.

If we assume a causal association between the school environment and weight status, the finding that the variation attributed to differences at the school level was greater in reception compared to year 6 seems counterintuitive, as one might expect the school impact to be more in the children who have attended school for longer. A possible explanation is that the influence of the school on children's behaviour changes as they move through the school. For example, the environment for reception year children may be much more conducive to physical activity (e.g. active play facilities and sessions) than the environment for year 6 children, where there may be more emphasis on academic attainment. Extending this scenario, it is possible that for older children, schools are more constrained by national targets around academic attainment, and so there is less variation between them in terms of their influence on childhood obesity. This possible differential influence of schools on different age groups merits further exploration. Another potential explanation is that the school effect on older pupils is diluted by influences external to the school environment. For example, older children may choose more sedentary behaviours outside of school, or have more freedom to choose what they eat. Developing a further understanding of both school and external influences will inform future intervention development.

The association observed between BMI and school time spent in physical education adds to emerging evidence that suggests school physical activity environments are an important focus for intervention, particularly in younger children. A US study explored the effect of increased physical education time on change in BMI as children moved from kindergarten to first grade and found a beneficial effect of more physical education.[38] Another US study explored the longitudinal effects of home and school characteristics on children's BMI and found that longer school break times were associated with slower BMI growth.[39] In addition, school-based physical activity interventions have shown promise in reducing overweight and obesity[10,12], especially those with a compulsory physical activity element.[40]

In conclusion, this study demonstrates a variation in weight status between schools that is not explained by sociodemographic characteristics of the pupils. Time devoted to school physical education, and possibly other physical activity characteristics may influence childhood weight status, especially in young children. In the UK national policy is in place to ensure at least two hours of physical education per week[9,41], but given our findings, more extreme policy intervention may be required to affect enough change to school physical activity environments to significantly influence children's physical activity levels and weight status. More research is required to further characterise school physical activity environments and determine their influence on childhood obesity. In the meantime policymakers should continue to put in place measures to ensure healthy school environments.

CONTRIBUTORSHIP STATEMENT

M Pallan participated in the study design and analysis, and drafted the manuscript. P Adab participated in the study design, analysis and helped draft the manuscript. A Sitch developed and undertook the multilevel modelling methodology and helped draft the manuscript. P Aveyard had overall responsibility for the study and participated in study design, analysis, and helped draft the manuscript. All authors had full access to all of the data in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. All authors read and approved the final manuscript.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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WHAT IS ALREADY KNOWN ON THIS TOPIC

Environmental influences on childhood obesity are important.

Schools are one aspect of a child's environment and changes to the school environment can be used as an intervention to reduce obesity.

The features of the school environment that influence obesity are unknown.

WHAT THIS STUDY ADDS

Most variation in BMI between primary schools is explained by individual differences.

Some variation in BMI can be explained by differences in school characteristics.

Some of this school level variation is explained by the amount of time schools devote to physical education.

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